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SHORT COMMUNICATION

Selecting Species for Passive and Active Riparian Restoration in Southern Mexico

Paula Meli,[1,2,3] Miguel Martínez-Ramos,[4] and José M. Rey-Benayas[2]

Abstract

In revegetation projects, distinguishing species that can be passively restored by natural regeneration from those requiring active restoration is not a trivial decision. We quantified tree species dominance (measured by an importance value index, IVI_i) and used abundance–size correlations to select those species suitable for passive and/or active restoration of disturbed riparian vegetation in the Lacandonia region, Southern Mexico. We sampled riparian vegetation in a 50 × 10–m transect in each of six reference (RE) and five disturbed (DE) riparian ecosystems. Those species representing more than 50% of total IVI in each ecosystem were selected, and Spearman rank correlation between abundance and diameter classes was calculated. For eight species, it was determined that passive restoration could be sufficient for their establishment. Another eight species could be transplanted by means of active restoration. Five species regenerate well in only one ecosystem type, suggesting that both restoration strategies could be used depending on the degree of degradation. Finally, two species were determined to not be suitable for restoration in the RE (based on the above selection criteria) and were not selected during this initial stage of our restoration project. The high number of tree species found in the RE suggests that the species pool for ecological restoration is large. However, sampling in both ecosystem types helped us reduce the number of species that requires active restoration. Restoration objectives must guide the selection of which methods to implement; in different conditions, other criteria such as dispersal syndrome or social value could be considered in the species selection.

Key words: **indicators, Lacandonia, natural regeneration, rainforest, recovery.**

Introduction

An aim of ecological restoration is to reestablish the characteristic species assemblage in a degraded or destroyed ecosystem and appropriate community structure occurring in the reference ecosystem (Society for Ecological Restoration International Science and Policy Working Group, SER 2004). Many tropical and humid temperate ecosystems can recover with little or no human intervention when the soil has not been severely degraded (González-Espinosa et al. 2007). In these cases, "cessation of activities that are causing degradation or preventing recovery" (passive restoration, Kaufmann et al. 1997) is enough to drive ecosystem recovery, and can be considered the first step in ecological restoration (Rey-Benayas et al. 2008). However, although passive restoration sometimes may be sufficient for some species, others need active restoration. Revegetation—the deliberate introduction of native species—is one of the tools most frequently used in ecological restoration, but it is usually time-consuming and expensive. Therefore, distinguishing species that can be passively restored by natural regeneration from those species requiring active restoration can greatly reduce the cost and effort of a restoration project. However, making this determination is not simple. Our main goal in the initial stage of this restoration project, based in the Lacandonia region of Southern Mexico, is selecting species of riparian vegetation for passive and active restoration.

Methods

The study was conducted in Marqués de Comillas Municipality (16°54′N, 92°05′W) in the Lacandonia region, Southern Mexico. Mean annual precipitation is about 3,000 mm and a short dry season (<100 mm/month) occurs between January and April (Martínez-Ramos et al. 2009). Humans settled in this region during the early 1970s and former rainforest has been extensively converted to agricultural fields (De Jong et al. 2000).

Our reference ecosystem (RE) consisted of six pristine riparian areas. Our disturbed ecosystem (DE) included five areas that were completely deforested, and later abandoned for 3–10 years. Presently, DE areas are covered by secondary riparian vegetation. In each study area, we sampled riparian

[1]Natura y Ecosistemas Mexicanos A.C., San Jacinto 23-D, Col. San Ángel, CP 01000, México D.F., México
[2]Departamento de Ecología, Edificio de Ciencias, Universidad de Alcalá, 28871 Alcalá de Henares, Madrid, Spain
[3]Address correspondence to P. Meli, email paula@naturamexicana.org.mx
[4]Centro de Investigaciones en Ecosistemas, Universidad Nacional Autónoma de México, Antigua Carretera a Pátzcuaro No. 8701, CP 58190, Morelia, México

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vegetation in a 50×10–m transect, where we measured the height and diameter at breast height (dbh) of all trees with dbh greater than 1.5 cm. The dbh data were converted to basal area values using $\pi \times (\text{dbh} \times 0.5)$. For each transect and species, we calculated an importance value index (IVI_i) as the sum of the species' relative density, relative frequency, and relative basal area divided by 3 (Curtis & McIntosh 1951). Our analysis was restricted to those species with the greatest IVI_i and that together covered more than 50% of total IVI_i in each ecosystem. For each transect, we calculated each species' abundance (N_i, number of stems of species i per transect) in each of 11 dbh classes (from 0 to >50 cm, with 5-cm intervals). For each transect and species, we calculated the correlation (Spearman rank correlation, r_s) between abundance [$\log(N_i + 1)$] and the midpoint of the dbh classes (hereafter called abundance–size correlation). A high regeneration potential was represented by a diminishing number of individuals as diameter size increased. This trend resulted in a high negative correlation (high availability of small-sized trees), and therefore an acceptable potential for passive establishment of the species. A positive or nonsignificant correlation (lack of small-sized trees) meant that the species does not establish naturally and therefore needs to be actively restored.

Results

A total of 115 species were found in RE, whereas a total of 97 species were found in DE. The first 15 species (Table 1) accounted for 54 and 51% of the total IVI_i in the RE and DE, respectively. Of these 30 species, 5 were common to RE and DE (*Albizia leucocalyx*, *Ampelocera hottlei*, *Croton schiedeanus*, *Dialium guianense*, and *Ficus* sp.), and 2 were absent in the RE. We therefore characterized 23 species for restoration assessment (Table 1).

Eight species showed negative abundance–size correlation and were significant ($r_s < -0.6$, $p < 0.05$) in both ecosystem types, suggesting that passive restoration could be sufficient for their successful establishment (Table 1). At the other extreme, eight species were either absent in DE or the abundance–size correlation was not significant, suggesting that these species could be introduced by active restoration. Five species regenerate well in only one or the other of the two ecosystem types, suggesting that either strategy could be used, mainly depending on the degree of degradation. Finally, two species regenerate well in DE but have the lowest IVI in RE, and were not selected for restoration at least at this first stage of the project.

Discussion

Interpretation of the IVI_i and abundance–size correlations resulted in a preliminary list of 20 species potentially useful for restoration of Lacandonian riparian vegetation and provided recommendations for possible restoration strategies for particular species. The high number of tree species found in RE shows that the species pool for ecological restoration is large; sampling in both ecosystem types helped us develop

Table 1. Species importance value index (IVI) and Spearman rank correlation coefficient (r_s) in reference and disturbed riparian ecosystems for 23 native tree species found in the Lacandonia region, and recommendation for restoration (passive, active, or nonselected [NS]).

Species	*Family*	*Reference Ecosystem*			*Disturbed Ecosystem*			*Restoration Recommendation*
		IVI	r_s	*p*	*IVI*	r_s	*p*	
Ficus sp.	Moreaceae	10.145	0.5	0.1173	2.212	−0.1	0.7699	Active
Cojoba arbórea	Mimosoideae	6.264	−0.2089	0.5376	0.504	−0.4	0.2229	Active
Dialium guianense	Caesalpinoideae	5.305	−0.485	0.1305	5.018	0.051	0.8817	Active
Protium sp.	Burseraceae	4.781	−0.7862	*0.0041*	2.365	−0.7862	*0.0041*	Passive
Ampelocera hottleii	Ulmaceae	4.394	−0.5625	0.0717	1.233	−0.7747	*0.0051*	Passive/active
Brosimum alicastrum	Moreaceae	3.494	−0.2293	0.4975	0.485	−0.5	0.1173	Active
Brosimum costarricanum	Moreaceae	2.854	−0.2132	0.5291	—	—	—	Active
Guarea glabra	Meliaceae	2.851	−0.6742	*0.0229*	0.356	−0.7659	*0.006*	Passive
Croton schiedeanus	Euphorbiaceae	2.316	−0.7551	*0.0072*	5.039	−0.917	*<0.0001*	Passive
Pouteria durlandii	Sapotaceae	2.305	−0.887	*0.0003*	1.201	−0.6068	*0.0478*	Passive
Calophyllum brasiliense	Clusiaceae	1.995	−0.4842	0.1313	0.622	−0.5	0.1173	Active
Nectandra sleneri	Lauraceae	1.898	−0.7862	*0.0041*	—	—	—	Active
Albizia leucocalyx	Mimosoideae	1.892	−0.8522	*0.0009*	4.223	−0.2582	0.4433	Passive/active
Vochysia guatemalensis	Vochysiaceae	1.864	−0.1195	0.7263	2.004	−0.3772	0.2528	Active
Eugenia mexicana	Myrtaceae	1.777	−0.8291	*0.0016*	0.831	−0.5	0.1173	Passive/active
Castilla elastica	Moreaceae	1.554	−0.7974	*0.0033*	3.648	−0.7862	*0.0041*	Passive
Spondias mombin	Anacardiaceae	0.885	−0.5164	0.1039	3.235	−0.8449	*0.0011*	Passive/active
Inga vera	Mimosoideae	0.859	−0.8315	*0.0015*	3.896	−0.6116	*0.0456*	Passive
Lonchocarpus guatemalensis	Papilionoideae	0.725	−0.7659	*0.006*	2.956	−0.5745	0.0645	Passive/active
Cecropia peltata	Cecropiaceae	0.635	−0.7946	*0.0035*	4.779	−0.8318	*0.0015*	Passive
Orthion subsessile	Violaceae	0.548	−0.6607	*0.0269*	2.068	−0.7833	*0.0043*	Passive
Piper sp.	Piperaceae	0.278	−0.5	0.1173	2.275	−0.7862	*0.0041*	NS
Schizolobium parahybum	Caesalpinoideae	0.117	−0.1	0.7699	4.306	−0.8102	*0.0025*	NS

p Value in italics indicates that the value is significant. (—) indicates the absence in DE.

a comprehensive species list based on their abundance and size. However, the predictive potential of the abundance–size correlations could be limited by our study's small sample size, because in both of our ecosystem types the relative abundance distribution showed the typical hyperbolic curve, with few abundant species and quite rare species (personal observation). Furthermore, the predictive value of abundance–size correlations could decrease as age of DE increases and species composition begins to resemble that of the RE.

Our method did not target some pioneer species (*Schizolobium parahybum*, *Piper* sp.) because of their ability to establish naturally in degraded areas. Such pioneer species may not be the most suitable species, in economic terms, when degradation is not very severe, as in our study. Where land degradation is severe, as in degradation caused by mining (Sharma & Sunderraj 2005), or with specific problems such as high erosion on steep slopes (Dos Santos et al. 2008), the use of pioneer species adapted to grow on disturbed or degraded ecosystems could be recommended for active restoration.

We concluded that our method is useful to select species for restoration because of its relatively low cost and simplicity, which makes it accessible to different stakeholders. It could be applied in other tree-dominated ecosystems, but its use would be limited in grasslands or other ecosystems where species regeneration is difficult to estimate. Finally, as in any restoration project, the method selected depends on the main objectives. In different conditions, other criteria could be considered in species selection, including soil adaptive capacity (Sharma & Sunderraj 2005), social values (cf Moreno-Cassasola & Pardowska 2009), and dispersal syndromes (Sansevero et al. 2009). Rare species such as shrubs and herbaceous species are also important, but not necessarily at early stages of restoration.

Implications for Practice

- At the early stages of restoration of tree-dominated ecosystems, the combination of species dominance indexes (e.g. IVI_i) and abundance–size correlations could be used to select a preliminary list of species suitable for passive or active restoration.
- Species that establish by natural regeneration could be used in passive restoration actions when ecosystems are not severely degraded.

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